Patient Transfer: Risk of Back Injury and Low-Back Pain in Healthcare Workers

A prospective study combining technical measurements and epidemiology

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BY
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AALBORG UNIVERSITY
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- **Vinstrup, J**., Madeleine, P., Jakobsen, M.D, Andersen, L.L., 2019. *Physical Exposure Profile of Patient Transfer and Risk of Back Injury & Low Back Pain: Prospective Cohort Study.* Submitted.

- **Vinstrup, J**., Madeleine, P., Jakobsen, M.D, Andersen, L.L., 2019. *Biomechanical Load during Patient Transfer with Assistive Devices: Cross-sectional Study.* Submitted.

- **Vinstrup J**, Jakobsen MD, Calatayud J, Jay K, Andersen LL. *Association of Stress and Musculoskeletal Pain With Poor Sleep: Cross-Sectional Study Among 3,600 Hospital Workers.* Front Neurol. November 2018.

- **Vinstrup J**, Madeleine P, Jakobsen MD, Jay K, Andersen LL. *Patient transfers and risk of back injury: protocol for a prospective cohort study with technical measurements of exposure*. JMIR Research Protocols. November 2017.

- **Vinstrup J**, Skals S, Calatayud J, Jakobsen MD, Sundstrup E, Pinto ND, Izquierdo M, Wany Y, Zebis MK, Andersen LL. *Electromyographic evaluation of high-intensity elastic resistance exercises for lower extremity muscles during bed rest*. European Journal of Applied Physiology, May 2017.

- **Vinstrup J**, Calatayud J, Jakobsen MD, Sundstrup E, Jørgensen J, Casaña J, Andersen LL. *Hand exercises in chronic stroke patients: Dose-response and exercise comparison using electromyography*. Journal of Hand Therapy, May 2017.

- **Vinstrup J**, Calatayud J, Jakobsen MD, Sundstrup E, Jay K, Brandt M, Zeeman P, Jørgensen J, Andersen LL. *Electromyographic comparison of conventional machine strength training versus bodyweight exercises in patients with chronic stroke*. Topics in Stroke Rehabilitation, May 2017.

- **Vinstrup J,** Calatayud J, Jakobsen MD, Sundstrup E, Andersen LL. *Focusing on Increasing Velocity during Heavy Resistance Knee Flexion Exercise Boosts Hamstring Muscle Activity in Chronic Stroke Patients*. Neurology Research International, July 2016.

- **Vinstrup J**, Calatayud J, Jakobsen MD, Sundstrup E, Jay K, Brandt M, Zeeman P, Jørgensen J, Andersen LL. *Electromyographic comparison of elastic resistance versus machine exercise for high-intensity strength training in chronic stroke patients*. Archives of Physical Medicine and Rehabilitation, March 2016.

- **Vinstrup J**, Sundstrup E, Brandt M, Jakobsen MD, Calatayud J, Andersen LL. *Core muscle activity, exercise preference and perceived exertion during core exercise with elastic resistance versus machine*. Scientifica, October 2015.

Preface

This project is a collaboration between the National Research Centre for the Working Environment and Aalborg University, Department of Health Science and Technology. It was funded by a grant from the Danish Working Environment Research Fund (grant number AMFF 26-2015-09) and was awarded the Elite Research Travel Grant in 2018, distributed by the Ministry of Higher Education and Science.

Unfeigned gratitude is due not only to my esteemed supervisors but also to the members of the research-group; generously gracing me with their presence and insights. Likewise, Marianne Kjeldsen, Aalborg University Hospital, proved an invaluable help in recruiting healthcare workers from all over the region. Without her, I would doubtfully have gained the trust of the inner circle.

This is by no means a short read. However, nor is it needlessly extended to the point where it requires several refills. This is by design. Words matter, specificity matters, and I see no justification in providing superfluous information. For the same reason, the thesis is meant to be read in one setting and is therefore written in a language that allows for this while by no means compromising the sciency stuff. However, with the goal of making it not only marvelously interesting but also a comfortable read, naturally occurring intermissions are included along the way. These are meant to guide you through the experience to come. Likewise, the included quotes are designed to summarize as well as to give pause and foster reflection.

We will be diving into the aches & pains of Danish healthcare workers, so sit back, pop your favorite nootropics and brace yourself.

October 2019

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English summary

The healthcare industry experiences a high prevalence of musculoskeletal disorders, shortage of nurses and a high frequency of lifting-related injuries. This often results in high rates of sickness absence, job insecurity and loss of productivity. Therefore, this project aimed to investigate the preventative effect of decreasing physical load during patient transfer via the use of assistive devices; in relation to which a protocol article (study I) was published prior to data collection. Measurements of muscle activity and trunk inclination were performed during full workdays at Danish hospitals, hereby creating a load index of commonly used assistive devices (study II). The results from the technical measurements showed that the use of technical-advanced assistive devices (i.e. the ceiling-lift and intelligent bed) resulted in lower physical load compared to not using assistive devices. Following this, the load index was applied to a prospective cohort of healthcare workers (study III): The results from this analysis demonstrated that low physical exposure during patient transfer is associated with lower intensity of low-back pain at 1-year follow-up, while not being a significant risk factor for back injury. In conclusion, increased use of specific assistive devices results in decreased physical load and may be beneficial in terms of preventing low-back pain in healthcare workers. Future multifaceted interventions should investigate the efficacy of these assistive devices alongside the myriad of other relevant factors specific to the patient transfer scenario, while ensuring feasible implementation strategies relevant to the local working environment.

Danish summary

Sundhedssektoren er præget af en høj forekomst af muskelskeletale smerter, mangel på sygeplejersker samt en høj hyppighed af løfterelaterede skader. Resultatet af dette afspejles bl.a. i højt sygefravær, jobusikkerhed og produktivitetstab. Selvom akkumuleret fysisk belastning ser ud til at udgøre en potent risikofaktor, savnes der langtidsholdbare effekter. Dette projekt havde til formål at belyse effekten af fysisk belastning under patientforflytning ift. udviklingen af lænderygssmerte og rygskader, hvortil en protokol artikel (study I) blev publiceret forud for dataindsamling. Målinger af muskelaktivitet og overkrops-positioner blev foretaget under hele arbejdsdage på danske hospitaler, og på baggrund af disse tekniske målinger blev der udviklet et belastningsindex for de hyppigst-anvendte hjælpemidler (study II). Resultaterne herfra viste at brugen af specifikke tekniske hjælpemidler, loftlifte og intelligente senge, resulterede i lavere fysisk belastning under patient forflytning sammenlignet med ikke at bruge et hjælpemiddel.
Herefter blev belastningsindexet appliceret på en prospektiv kohorte af plejepersonale fra danske hospitaler (study III). Resultaterne fra denne analyse viste at lav fysisk belastning var associeret med lavere intensitet af lænderygssmerte ved 1-års opfølgning, mens risikoen for rygskade ikke var påvirket. På baggrund af disse resultater konkluderes det derfor at øget brug af specifikke hjælpemidler resulterer i lavere fysisk belastning under patient forflytninger, og at dette muligvis kan medvirke til at forebygge udviklingen af lænderygssmerte. Eftersom et utal af indflydelsesrige faktorer spiller ind på brugen af hjælpemidler anbefales det at fremtidige interventioner så vidt muligt tager højde for flere af disse, sideløbende med udviklingen af realistiske implementeringsstrategier rettet mod det specifikke arbejdsmiljø.

List of abbreviations and tables/figures

EMG	electromyography
LBP	low-back pain
BMI	body mass index
MVC	maximal voluntary contraction
IED	interelectrode distance
RMS	root mean square
nRMS	normalized root mean square
OR	odds ratio
GDPR	general data protection regulation
LOTR	lord of the rings

List of studies

The following depicts the studies completed within the theme of this project (2016-2019). Studies I, II and III listed below are integral parts of this thesis, whereas other articles published within this timeframe are listed in the curriculum vitae.

Study I

Vinstrup, J., Madeleine, P., Jakobsen, M.D., Jay, K., Andersen, L.L., 2017. *Patient Transfers and Risk of Back Injury: Protocol for a Prospective Cohort Study With Technical Measurements of Exposure*. JMIR Res Protoc 6, e212. https://doi.org/10.2196/resprot.8390

Study II

Vinstrup, J., Madeleine, P., Jakobsen, M.D, Andersen, L.L., 2019. *Biomechanical Load during Patient Transfer with Assistive Devices: Cross-sectional Study.* Submitted.

Study III

Vinstrup, J., Madeleine, P., Jakobsen, M.D, Andersen, L.L., 2019. *Physical Exposure Profile of Patient Transfer and Risk of Back Injury & Low Back Pain: Prospective Cohort Study.* Submitted.

Introduction

1.1 Background

Musculoskeletal disorders (MSDs) are frequently reported among healthcare workers, with a 1-year prevalence reported at 55% for low-back pain (LBP) (Davis and Kotowski, 2015). LBP thereby represents the most commonly reported MSD, followed by issues related to the neck and shoulders (Davis and Kotowski, 2015; Ribeiro et al., 2017). Further, the reported prevalence is higher among healthcare workers compared with other groups of the working population (Cohen-Mansfield et al., 1996; Guo et al., 1995; Yang et al., 2016), and the frequency of back injuries have been reported to be six times that of other professions (Cohen-Mansfield et al., 1996). Following this, it is not surprising that 37% of Danish nurses report experiencing pain several times during the week (National Research Centre for the Working Environment, 2018); the consequences of which often leading to increased rates of sickness absence and loss of productivity (Andersen et al., 2012; Hansson and Hansson, 2005). Therefore, aside from the individual burden of living with LBP (Snelgrove and Liossi, 2013), the socioeconomic costs attributed to LBP are increasingly high (Sterud and Tynes, 2013).

The current situation in the healthcare profession is further worsened by the fact that the industry is experiencing a global shortage of nurses; one that is estimated to increase by 2030 (Zhang et al., 2018). It is likely that part of the reason for this present and future shortfall is due to factors related to the local working environment, which is known to foster high ratings of perceived exertion (Vieira et al., 2006), high levels of fatigue and stress (Zboril-Benson, 2002) as well as the aforementioned high prevalence of MSDs (Ribeiro et al., 2017).

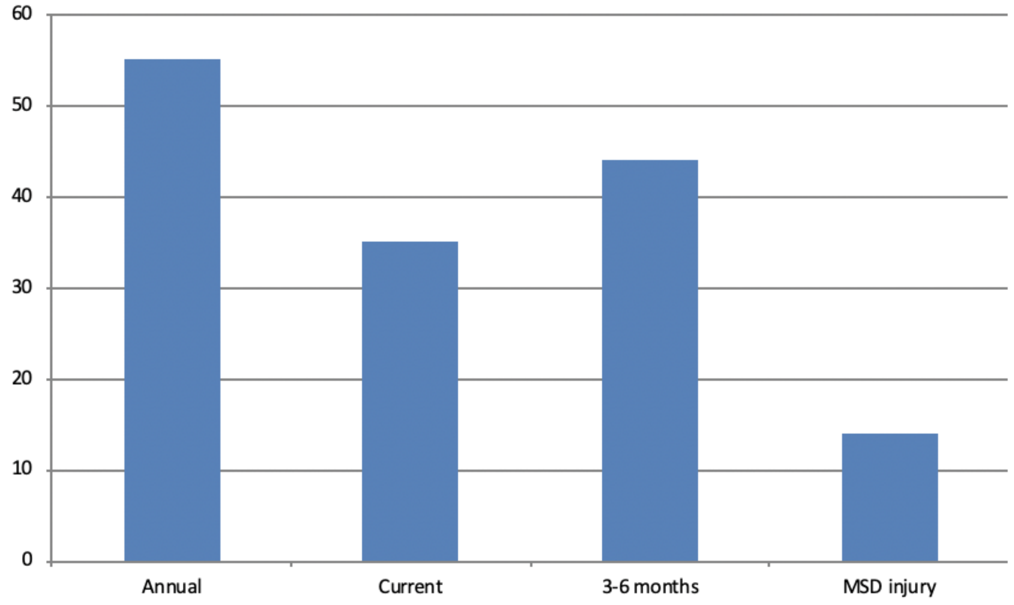

Figure 1 - Prevalence of LBP among nurses and nursing aides: previous 12 months, current (less than a week), 3-6 months and musculoskeletal injury (adapted from Davis and Kotowski, 2015).

A vast number of projects have sought to reduce the prevalence and consequences of work-related MSDs among healthcare workers (Richardson et al., 2018). As such, interventions ranging from implementing lift systems to walking in unstable shoes have been tried and tested within this subgroup of the working population (Anyan et al., 2013; Vieira and Brunt, 2016). A noticeable proportion of these interventions have aimed to elucidate the effects of decreasing the physical workload (Richardson et al., 2018), as accumulated physical load constitutes a recurrent risk factor in the literature (Andersen et al., 2016; Coenen et al., 2014b; Møller et al., 2019; Oakman et al., 2017). Within this biomechanical perspective of the issue, a high frequency of heavy lifting, prolonged static work postures, bending- & rotation of the trunk and repetitive arm movement have indeed been associated with increased risk of work-related MSDs (Burdorf and Sorock, 1997; Hanvold et al., 2019; Ribeiro et al., 2017). Furthermore, a review by Coenen et al. found an exposure-response relationship between occupational lifting and occurrence of LBP in workers, and report that both intensity and frequency of lifting predict this occurrence (Coenen et al., 2014a).

Specific to the notorious working environment within the realm of healthcare, prospective cohort studies have shown that strenuous work-related physical exertion constitutes a potent risk factor for developing LBP (Andersen et al., 2013; Jensen et al., 2012) as well as increases the risk of back injury (Andersen et al., 2014).

"There is an absence of high quality published studies investigating interventions to protect nurses from musculoskeletal injuries and pain." (Richardson et al., 2018).

Contrary to what one might gather from following various media outlets, the finding that the healthcare profession seems cursed with a high prevalence of work-related MSDs, perhaps in part due to excessive physical workload, is not a new phenomenon (McAbee, 1988; Owen, 1989; Owen and Garg, 1991; Skovron et al., 1987). For example, Stobbe et al. reported more than three decades ago that frequency of patient transfer is associated with risk of back injury (Stobbe et al., 1988); a finding which have since been replicated in the literature (Andersen et al., 2014; Eriksen, 2004; Holtermann et al., 2013; Retsas and Pinikahana, 2000). The fact that strenuous occupational lifting - especially when performed repetitively in challenging and/or unaccustomed body positions - is associated with adverse outcomes, is also reflected in the opposite notion that decreasing physical exertion during work often leads to positive outcomes in terms of LBP (Coenen et al., 2014a; Stevens et al., 2019). Again, in relation to the myriad of physical- and psychosocial factors than constitute the turbulent working environment within healthcare (Oakman et al., 2017; Yang et al., 2016), it should therefore come as no surprise that increased use of appropriate assistive devices represents a favored approach to reduce the physical workload among healthcare workers (Alamgir et al., 2008; Chhokar et al., 2005; Collins et al., 2004; Koppelaar et al., 2012). In fact, previous studies not only report associations between infrequent use of assistive devices and increased risk of MSDs (Engkvist et al., 2000; Holtermann et al., 2015, 2013), but also between frequent use and decreased risk (Andersen et al., 2014; Boocock et al., 2019; D'Arcy et al., 2012; Garg and Kapellusch, 2012; Martin et al., 2009). For example, an important finding from the prospective cohort study by Andersen et al. is that the personnel who used assistive devices during the majority ("often" and "very often") of patient transfers, experienced a markedly lower risk of lifting-related accidents (odds ratio 0.59-0.62) compared to their peers who seldom engaged in the use of assistive devices (Andersen et al., 2014).

"From this analysis, it appears that patient lifting frequency is indeed a causative factor in the production of low-back injuries in nursing personnel." (Stobbe et al., 1988).

Following this, the majority of studies mentioned above have either taken advantage of the advancement and increasing use of technical measurements to obtain objective indications of biomechanical load or utilized questionnaire-based designs to estimate the physical workload within a population. The former has made it possible to wirelessly record electromyographic signals and angular displacement during prolonged real-life tasks (Jakobsen et al., 2018), whereas the latter design often utilizes job-exposure matrices to quantify exposure (Benke et al., 2000). As the combination of these methods is used in this thesis, strengths and shortfalls will be discussed in the next section.

Collectively and based on the cited literature, it seems evident that physical workload not only represents a salient piece in the enigma that concocts the high prevalence of pain and injury among healthcare workers, but also serves as one of numerous explanatory factors as to why several of the abovementioned interventions are deemed successful. Specifically, physical workload, frequency of patient transfers as well as insufficient use of appropriate assistive devices all appear to pose risk factors for MSDs among healthcare workers, while the combination of technical measurements and survey-information about task exposure provide opportunity to quantify physical workload.

"Back injury may be the single largest contributor to the nursing shortage."

(Edlich et al., 2005)

1.2 Aims and hypotheses

Following this line of reasoning with emphasis on the latter risk factor mentioned above, it seems the practical applicability still lacks detail and specificity. In other words, while it is somewhat clear that appropriate use of assistive devices diminishes the physical load, it is presently unknown whether this effect is due to a specific category of equipment or if it´s related to consistent use of a combination of different assistive devices. It is not unlikely that some assistive devices are inherently more effective than others in terms of decreasing the physical load during patient transfers. However, because most interventions to date have focused on the general use of assistive devices, this question remains largely unanswered in the literature.

Therefore, the aims of this PhD project were to:

- Identify the use of assistive devices during patient transfers among a population of Danish healthcare workers (study II).
- Quantify the physical load associated with the use of each assistive device and develop an exposure matrix based on technical measurements of biomechanical load (study II).
- Investigate associations between physical exposure and the risk of back injury and LBP based on the exposure matrix applied to a prospective cohort of healthcare workers (study III).

A study protocol (study I) was published prior to data collection to ensure transparency of the scientific approach. Figure 2 depicts a flowchart of the included studies and their purpose.

The statistical research question of study II was to test whether the null-hypothesis of no difference in biomechanical load between the use of various assistive devices and no assistive device could be rejected. In study III, the null-hypothesis stated that no differences exist between different levels of physical exposure and the risk of back injury and LBP.

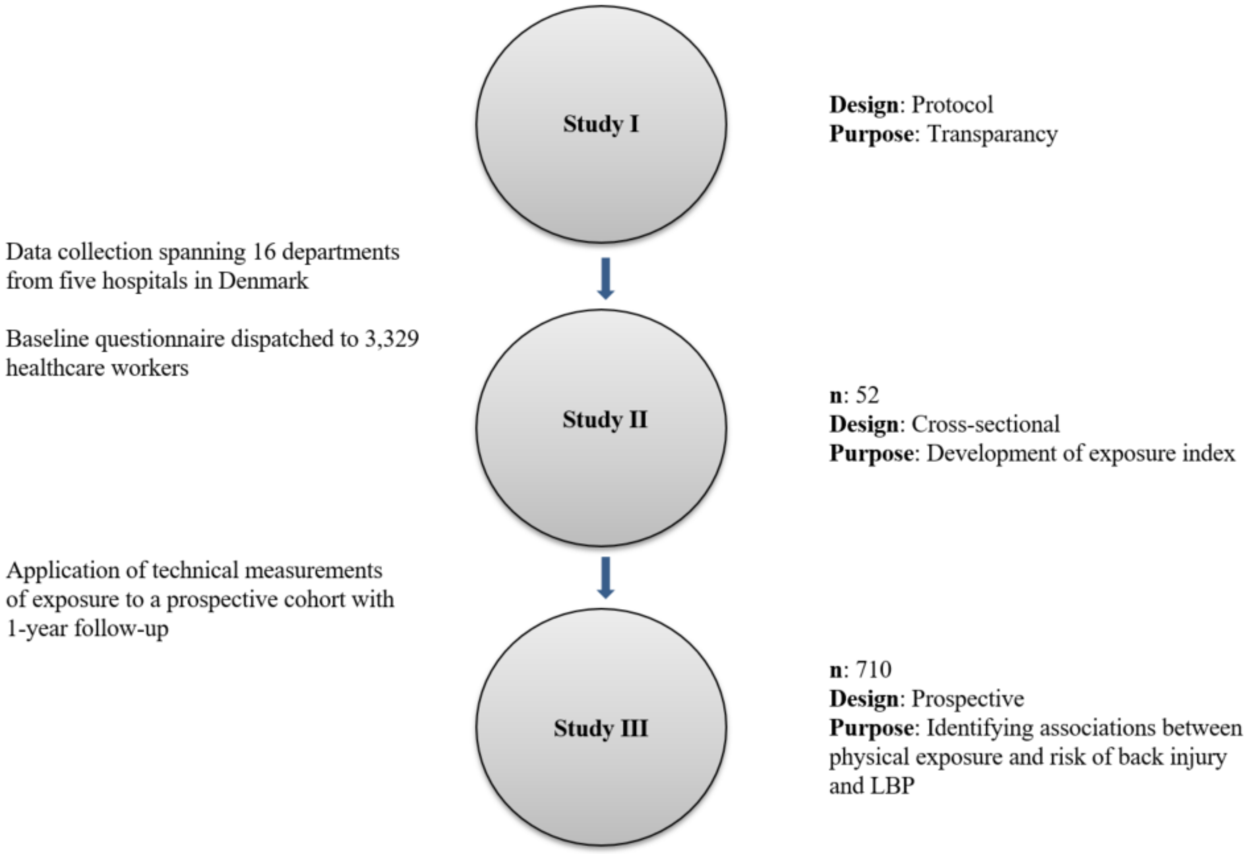

Figure 2 - Flowchart of included studies.

Methods

In order to achieve these aims, this project included technical measurements of physical exposure during patient transfers throughout a full workday and applied these on a large cohort of healthcare workers using a prospective questionnaire design with 1-year follow-up. The following section will describe the methods in detail as well as argue the rationale behind the choices made.

2.1 Overview

Starting from the top, a pilot study was conducted at Metropol, Copenhagen, Denmark, during the spring of 2017. The study consisted of measurements of surface electromyography (EMG) and actigraphy during standardized patient transfers involving 16 nursing students. In addition to gathering information on commonly used methods of patient transfer performed in a standardized setting, the pilot study served to familiarize and test the technical equipment before the commencement of data collection for this project.

Following this, the protocol article (study I) was published online on July 10, 2017, outlining the various methods and intentions of the project. Likewise, during the summer of 2017 the baseline questionnaire was dispatched to 3,329 healthcare workers from Danish hospitals; including questions regarding lifestyle, health and working environment. The recruitment of these recipients was done in collaboration with centrally positioned individuals within the regions, which - although not entirely unproblematic due to GDPR, numerous different databases and multifarious rules - in the end resulted in the relatively high number of recipients. The questionnaire design included a follow-up 1 year later; hereby allowing for prospective analyses of factors related to the working environment and their associations with outcomes related to MSDs (study III). Meanwhile, the recruitment of participants for the technical measurements was done via an immeasurable number of mails, phone calls, meetings and promises of lukewarm coffee. Department managers, head nurses and representatives from the working environment within Region Nord and Region Midt were invaluable collaborators in the recruitment process as well as booking of various locations throughout the hospitals for application of equipment and normalization procedures.

In addition to the protocol article mentioned above (study I), this thesis also contains a cross-sectional (II) and prospective (III) study. In short, study II evolves around the technical measurements and provides results on the physical load associated with each assistive device, whereas study III utilizes the prospective questionnaire data and includes associations between physical exposure and future risk of back injury and LBP. The methodological details of study II and III are discussed in sections 2.4.1.2 and 2.5, respectively.
Table 1 depicts an overview of the included outcome measures for study I, II and III.

Table 1 - Overview of design and outcomes.

Study		**I**	**II**	**III**
Study design	Study protocol	X		
	Cross-sectional		X	
	Prospective			X
Outcomes	Physical exposure		X	X
	Pain intensity		X	X
	Perceived exertion		X	
	Fatigue		X	
	Risk of back injury			X
	Risk of LBP			X

2.2 Subjects

Study II used a cross-sectional design to perform measurements of muscle activity and trunk positions during patient transfers. A grand total of 52 female health care workers (mean ± SD; age 42 ± 10y; height 167 ± 6cm.; body mass 67 ± 12kg) extended across 16 different departments from five hospitals in Denmark volunteered to participate in the technical measurements. Criteria for inclusion were measurements of blood pressure <160/100, the absence of pregnancy, progressive/life-threatening diseases as well as an estimated high number (>5) of full patient transfers during the workday. Because written information was sent out prior to enrolment and questions answered via mail, none of the participants were excluded on the day of testing.

Table 2 shows the characteristics of participants included in study II.

Study III utilized the results obtained from the technical measurements to create a matrix of exposure profiles and applied these to a prospective cohort. Partially based on the questions used in the Danish Work Environment Cohort Study (DWECS), a total of 1,285 participants were included as the fulfilled the following criteria: Females working as nurses, nurses´ aides and assistants, physio- or occupational therapist, radiographer or porter and who were engaging in daily patient transfers. Furthermore, the inclusion criteria included not having experienced back injury within the previous year as well as current LBP intensity <6 (0-10). 710 (55%) of the participants responded to the 1-year follow-up and were included in the analysis. Because we sought to investigate a potentially preventative effect of low physical exposure, the inclusion criteria were chosen in order to 1) achieve a population similar to that of the cross-sectional study (study II) and 2) diminish the confounding effect of recent back injury and/or current LBP.

Table 3 shows the characteristics of participants included in study III.

Table 2 - Characteristics of participants (n=52) included in the cross-sectional study. Adapted from study II.

	Mean	**SD**
Age (y)	42	10
Height (cm)	168	6
Body mass (kg)	67	12
Years as a healthcare worker (n)	15	9
Blood pressure (mmHg)	130/83	10/8
VAS (0-10)		
Low back	0.64	0.95
Neck/shoulder	0.50	1.02
Erector spinae maximal strength (N)		
Morning	247	62
Afternoon	229	65
Physical exertion during patient handling (0-10)	2.7	1.3

2.3 Ethics

In line with the Helsinki Declaration, all participants included in the cross-sectional study were informed about the content of the study protocol before providing written informed consent. For the technical measurements, the information was given both via email and verbally before the commencement of data collection (study II). The study was approved by the Danish National Committee on Biomedical Research Ethics (The local ethical committee of Frederiksberg and Copenhagen; H-3-2010-062) and the Danish Data Protection Agency (j.nr. 2015-41-4232). All data were de-identified and analyzed anonymously. According to Danish law, questionnaire studies do not need approval from ethical and scientific committees, nor do they require informed consent from participants (study III).

Table 3 - Characteristics of participants in the prospective cohort. Adapted from study III.

	Mean	SD	%
N	1285		
Female			100
Age (y)	46.8	11.3	
BMI	24.9	4.6	
Smoking (yes)			9
Years in profession	17.8	11.9	
Working hours/week	34.7	3.4	
LBP within the previous 4 weeks (0-10)	1.5	1.6	
Back injuries within the previous 12 months	0		
Frequency of patient transfers with more than 1 healthcare worker, ranging from "never", i.e. 0/4 to "always", i.e. 4/4:			
0/4			3.5
1/4			19.4
2/4			30.8
3/4			26.4
4/4			19.9
Frequency of patient transfers with patients being so self-reliant that no assistive device is necessary:			
0/4			17.5
1/4			31.3
2/4			30.9
3/4			20.3
4/4			0.0
Level of leisure-time physical activity within the previous 12 months:			
Sedentary			5.1
Light exercise >3/week			63.4
Moderate exercise >3/week			28.3
Vigorous exercise several times per week			3.2

2.4 Technical measurements

The following paragraphs describe the technical methods used in this thesis. While this section probably won't win The Blixen Literary Award anytime soon, it is essential to get an understanding of the methods that lay the foundation for study II and III:

In the case of the former, evaluation of electromyographic activity and trunk position constitute the technical measurements while the latter adds a prospective cohort design to these measurements.

2.4.1 Electromyography and actigraphy

2.4.1.1 Overview

The EMG signal is an arithmetic representation of the myoelectric activity generated in muscle fibers in response to activation by motor neurons, hereby comprised by both neural drive and muscle properties; i.e. initiated and controlled by the nervous system and dependent on the physiological properties of the muscle (Farina et al., 2014; Raez et al., 2006). In short, following the activation of a motor neuron and the propagation along the motor nerve, depolarization of the muscle membrane at the endplate causes an action potential (assuming the threshold of the motor unit is exceeded), which spreads along the surface of the muscle fiber membrane. By using a typical bipolar electrode configuration, the electrode site registers the sum of all the detectable active motor units in a so-called interference pattern; the raw EMG signal.

As a stand-alone methodology, the use and interpretation of EMG signals constitute a century-long and extensive field of research in and by itself, with the first recording of muscle activity dating back to 1890 where the term "electromyography" was introduced by Marey (Cram et al., 1998). Since then - and especially within the past 20 years - the research has progressed extensively and EMG is now frequently used in clinical diagnosis and biomedical applications (Raez et al., 2006). Because surface EMG constitutes the main method used in this project, it seems prudent to elaborate not only on its role in this thesis but also on potential shortcomings of the method: Firstly, it is well known that both inter-electrode distance (IED) and electrode location influence the EMG signal considerately (Farina et al., 2002): In fact, the recorded EMG amplitude has been shown to monotonically increase with increasing IED (Farina et al., 2002). Secondly, not only is the EMG signal inherently/annoyingly stochastic in nature, it is also subject to ”noise” (i.e. signal interference) and artifacts from various electrical sources. For example, in addition to subject-related factors such as skin temperature, number of active motor units, fiber diameter and tissue structure (e.g. amount of cutaneous fat), movement artifacts and electromagnetic interference from the surrounding environment are able to drastically influence the EMG signal (Chowdhury et al., 2013; Raez et al., 2006). Thirdly, even though the amplitude of the absolute EMG signal is commonly used to infer the intensity of neural drive and hence the force produced (Farina et al., 2014), this interpretation is only partially correct and very much dependent on several factors: For instance, it is well-established that the size of the action potential differs between motor units and across conditions, and that the sum of this action potential is less than the sum of amplitudes produced by the individual motor units (Keenan et al., 2006, 2005). In short, the relationship between the neural drive and recorded EMG amplitude cannot necessarily be considered linear, and measurements of absolute EMG values are inherently limited in their usefulness.

Therefore, minimizing these potential shortfalls by rigorous standardization and normalization procedures are essential for achieving reliable measurements. The practical application and standardization protocols utilized in this thesis are described in the next paragraph.

“The surface EMG signal represents the electrical activity generated in muscle fibers in response to the activation provided by innervating motor neurons.” (Farina et al., 2014).

2.4.1.2 Data collection

The EMG variable of interest in this thesis is the amplitude, represented by the root means square (RMS) value. In congruence with the topic of this thesis, the musculature of interest is localized to the region of the low-back. The electrode placement and normalization procedures described below are therefore related to the erector spinae muscles, while similar information regarding the trapezius muscles are described in excruciating detail in study I. It should be noted that measurements of the trapezius muscles are not part of the thesis, as these recordings were obtained with the purpose of performing future secondary analyses.

Measurements were recorded using wireless EMG equipment (TeleMyo DTS Telemetry, Noraxon, AZ, USA). The sampling rate was set at 1500 Hz with a bandwidth of 10-500 Hz, and the amplifier had a 16-bit A/D converter. Before placing the electrode pairs (Blue Sensor N-00-S, Ambu A/S, Ballerup, Denmark) bilaterally on the erector spinae musculature (longissimus; two finger widths lateral from L1, iliocostalis; one finger-width medial from the line of the posterior spinae iliaca superior to the lowest point of the rib at the level of L2 with an IED of 20 mm.) (Hermens et al., 2000), the skin was cleaned and slightly abraded with scrubbing gel (Acqua gel, Meditec, Parma, Italy). In contrast to most studies investigating the erector spinae muscle, both the longissimus- and iliocostalis parts of the muscle were included in order to merge these measurements into a single value representing the low-back; hereby gaining the added benefit of attaining a larger sample of recordings. Further, even though the cross-sectional study design and the normalization procedures described below render the matter somewhat redundant in terms of the aforementioned variability issues, the IED was chosen partially to be able to compare the results of the present study with the majority of studies utilizing the same IED. Additionally, although measured in the upper trapezius muscle, Farina et al. compared IEDs ranging between 5-40 mm and found the lowest minimal variation in RMS values to be occurring at 20-25 mm. (Farina et al., 2002). Lastly in the section, the sadistic choice of providing the participants with a miniscule of discomfort during electrode placement was made in order to minimize electrode motion artifacts by slight skin abrasion (Tam and Webster, 1977).

Trunk inclination was continuously measured using accelerometry (3D DTS accelerometer sensor, Noraxon, Arizona, USA). The EMG- and accelerometry data were sampled synchronously, using a 16-channel 16-bit PC-interface receiver (TeleMyo DTS Telemetry, Noraxon, Arizona, USA). The accelerometer was positioned on the low-back; 1 cm. above the sacroiliac joint. Controversy exists regarding the use of accelerometry to estimate segment position for non-static movements. However, recent validation studies - including concurrent video analysis - have demonstrated that the use of accelerometers during dynamic, non-standardized and "free-living" activities provides high sensitivity in discriminating between activities (Korshøj et al., 2014; Skotte et al., 2014; Stemland et al., 2015). Therefore, based on the literature and due to the fact that the movements performed in this project generally are characterized by low/moderate speed, the use of accelerometry to determine inclination was deemed appropriate.

Following application of the equipment described above, maximal voluntary contractions (MVC) were performed for the erector spinae muscles in the Biering-Sorensen position during the (early!) morning hours and again in the afternoon. Not only is this a commonly used position to test erector spinae muscle strength (Biering-Sørensen, 1984; Burden, 2010; Jackson et al., 2017), it is also a test that is possible to perform at even the most incapacious workplaces/offices as it requires minimal equipment and space. The normalization procedure for the accelerometer consisted of the upright/vertical static position maintained for 5 seconds, hereby using the gravitational line as reference.

Following the normalization procedures described above, the female ventured back into her habitat with the research leader and his sizeable equipment trailing dutifully behind (Figure 3). In short, measurements were performed during patient transfers throughout the full workday, while simultaneously recording the assistive devices utilized, the number of participating personnel, self-reliance, sex and anthropometrics of the patient in order to achieve a (more) detailed picture of the numerous variables influencing the transfer scenario (study II). During this, equipment probes were frequently (i.e. whenever possible) inspected prior to the next patient transfer to make sure they had not shifted in place. By a genteel display of patience, a total of 364 hours was spent gathering information about the intricacies of each individual patient transfer scenario. Figure 4 illustrates the most commonly used assistive devices and their groupings.

2.4.1.3 Data analysis

During off-site data analysis, all raw EMG signals were visually checked and digitally filtered using a Butterworth fourth-order high-pass filter (10 Hz cut-off frequency) and subsequently smoothed using a RMS filter with a moving window of 500 ms. For each individual muscle, the 95th percentile rank of the smoothed RMS signal was normalized (nRMS) to the maximal RMS value obtained during MVC. In this thesis, the 95th percentiles of nRMS represent the highest level of muscle activity (Jonsson, 1982; Trask et al., 2008), hereby further safeguarding against unwanted motion artifacts by excluding non-physiological sporadic increases in muscle activity.

The accelerometer signals were digitally filtered using a lowpass 4th order zero-lag Butterworth filter (3 Hz cutoff frequency) and converted from acceleration to inclination by double integration. The 95th percentile ranks of forward - and lateral trunk inclination angles were calculated with respect to the gravitational line obtained during the normalization procedure described previously.

Figure 3 - Illustration of the ingenious mode of equipment transportation (left), erector spinae MVC contraption (bottom right), EMG- & actigraphy instruments (middle right) and the coffee that glued it all together (top right).

2.5 Development of exposure profiles

The following paragraphs will elaborate on the methods used in developing the exposure index; based on the abovementioned technical measurements that constitute study II and the application of these measurements to the prospective cohort that constitutes study III.

Assuming you have made it this far without breaking the chronological order; well done! The technical part is (partially) over. Consider reclining slightly and let it sink in before proceeding.

As mentioned, this project utilized a prospective questionnaire design in order to gauge any potential preventative/perilous effect of physical load. In the employment of this method, both the advantages (e.g. large sample size) and potential disadvantageous (e.g. non-response bias, insensitive measures etc.) that are often intrinsic to this design, are acknowledged (Cheung et al., 2017; Choi and Pak, 2004; Jones et al., 2013). Furthermore, by creating the exposure matrix at the level of individual assistive devices, the commonly observed shortfalls with job-exposure matrices are lessened (Benke et al., 2000; Quinot et al., 2017). That is, instead of quantifying the average exposure of whole job-groups (e.g. nurses), the exposure matrix described below greatly increases the specificity by assigning each individual assistive device an independent exposure profile; hereby reducing exposure misclassification (Quinot et al., 2017).

By using the results from the technical measurements, the exposure index was created (Table 4). The measurements included 14 different assistive devices which were grouped according to function; e.g. the wheelchair and walking-rollator were characterized as “walking aids” whereas the turner transfer and stand-assist were characterized as “standing aids”. Additionally, the ceiling-lift and accompanying sling were regarded as one, resulting in a total of 9 groups of assistive devices.

The descriptive values (nRMS and trunk flexion) related to each assistive device are found in study II. These values were used to create the exposure profiles in the following manner:

"No assistive device" was used as reference with the value "1". All other assistive devices were assigned exposure profiles relative to this, based on their combined values from EMG- and accelerometer data. These values were divided by the reference to achieve a fraction (e.g. nRMS ceiling-lift/"no assistive device"; 24.0/27.9 = 0.86), and the average of the EMG- and accelerometer values was calculated. In order to weigh the contribution from EMG and kinematics measurements equally, the average of the two kinetic values was used to calculate the exposure profile (e.g. 22.3/36.5 = 0.61 and 24.8/32.1 = 0.77 for forward- and lateral flexion, respectively; average 0.69). Hereby, the average of forward- and lateral flexion represented "trunk flexion", which was then used to calculate the average of the EMG- and trunk flexion values (e.g. average of nRMS (0.86) and trunk flexion (0.69) = 0.77 for the ceiling-lift) (Table 4).

From the participants in the prospective cohort described in paragraph 2.2, we gathered information regarding frequency of use for each assistive device included in the technical measurements. Therefore, by using the calculated exposure profiles related to the individual assistive devices and the quantification of frequency of use, each participant was assigned individual exposure values (study III). That is, the more frequent the participant used a specific assistive device with a certain exposure profile, the closer the participant´s exposure value would be to that of the assistive device. The participants were then grouped into quartiles based on their exposure: The two middle quartiles (25-75%) were merged to represent the norm and reference population, whereas the 1st and 4th quartiles represented low and high exposure, respectively. Following this, we tested associations between low- and moderate exposure (1st quartile; n=175 vs. 2nd and 3rd quartiles, n=349) as well as between high- (4th quartile, n=186) and moderate exposure, for the outcomes described below.

2.5.1 Outcome- and control variables

The control variables are described in (further) detail in study III. The outcome variables were based on the following questions:

1) *Rate your average pain for the low-back within the previous 4 weeks (0-10).*
2) *Have you injured your back during patient transfer within the previous 12 months? (yes/no) (Recall if the accident happened suddenly and unexpectedly).*

In short, the control variables included frequency of patient transfer, use of each individual assistive device, frequency of transfers performed together with one or more colleagues, and self-reliance of the patients. All questions contained possible response-options ranging from 0/4 (almost never) to 4/4 (every time). Likewise, as this thesis reports analyses of both unadjusted and fully-adjusted values of LBP intensity and back injury at follow-up, the latter analysis controlled for the following confounders: Age, body mass index, sex, smoking, physical activity during leisure time, education, seniority, working hours, overall mental health, as well as work-related attitudes towards justice, teamwork, influence, emotional demands, clarity of tasks as well as management recognition and support. Furthermore, the fully-adjusted analysis also accounted for frequency and number of personnel participating in the patient transfer as well as patient self-reliance.

2.6 Statistics

Statistical analyses were performed using SAS statistical software (SAS Institute, Cary, NC). In study II, data were analyzed using linear mixed models with repeated measures. Estimates are presented as least square means and 95% confidence intervals for each assistive device.

In study III, associations with back injury as the outcome were modeled using logistic regression, whereas LBP was modeled as a continuous outcome using a linear mixed model. Results are presented as odds ratio and least square mean differences, respectively, for the 1^{st} and 4^{th} quartiles in relation to two middle quartiles. Both analyses were controlled for the covariates mentioned above, and estimates include 95% confidence intervals with a significance level set to 0.05.

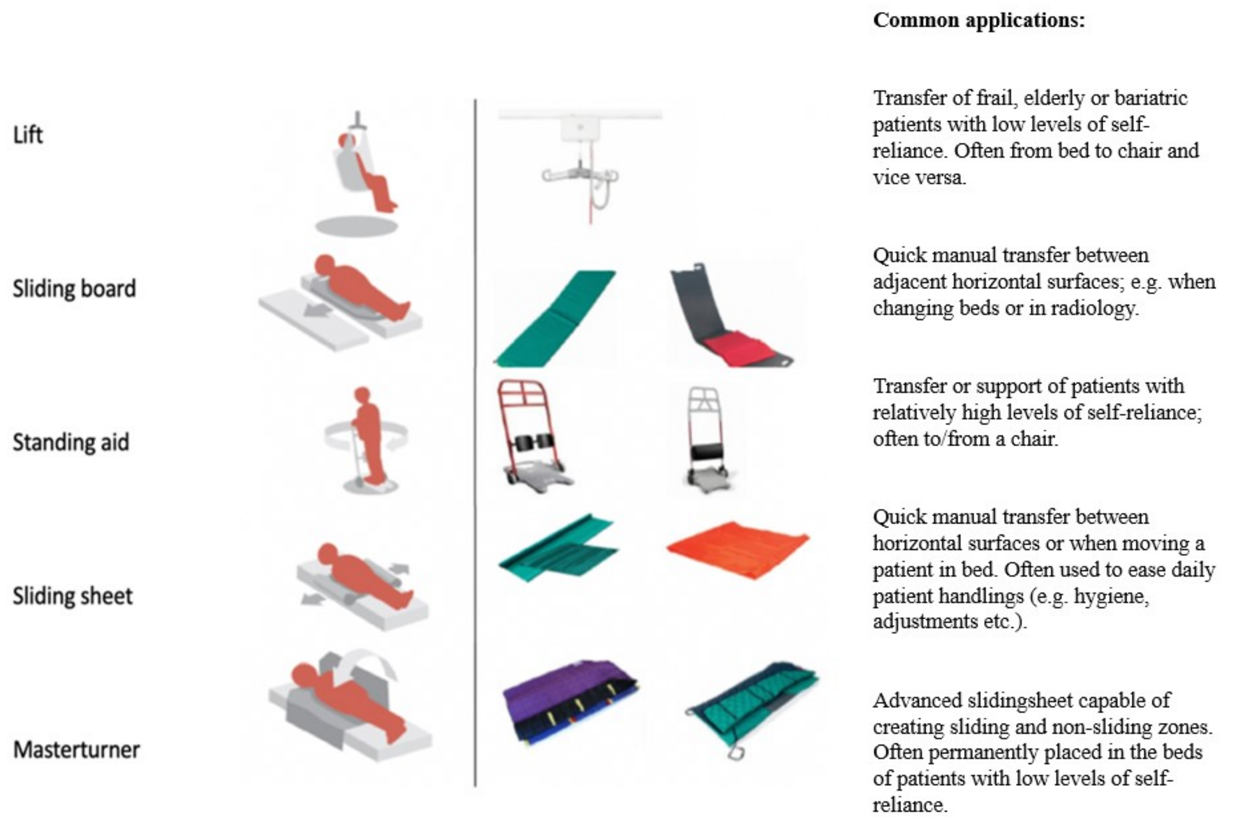

Figure 4: Illustration of commonly used assistive devices and their groupings. Adapted from study II with permission from Forflytningsportalen, Region Midtjylland.

Results

Based on the analyses described above, the results presented in this section report exposure profiles for each assistive device as well as fully-adjusted associations between physical exposure and risk of back injury and LBP, respectively. This is arguably the fun part. If you leaped somewhat lightly through the methods; no hard feelings. Carry on as you were.

Table 4 shows the individual exposure profiles for the 9 groupings of assistive devices included. In summary; ceiling lifts, intelligent beds, standing aids, masterturners, and regular hospital beds, in ascending order, all elicit relatively low physical exposure during patient transfer compared to no assistive device. The five most frequently observed types of patient transfers as well as indications of fatigue are reported in study II, which - based on 540 full transfers - also shows that 53% of these were performed without the use of assistive devices.

Table 4 - Exposure profiles for individual assistive devices. Based on study II and adapted from study III.

Assistive devices	Exposure Index	EMG	Forward flexion	Lateral flexion
No assistive device	**1**	1	1	1
Hospital bed	**0.8600**	0.9211	0.5492	1.0486
Intelligent bed	**0.8246**	0.8566	0.6792	0.9060
Bed sheet	**1.0289**	1.0968	1.0065	0.9155
Walking aids	**1.0200**	0.9892	1.0440	1.0573
Masterturner	**0.8582**	0.9606	0.7903	0.7215
Sliding sheet	**1.0109**	1.0860	1.0455	0.8259
Ceiling-lift	**0.7762**	0.8602	0.6123	0.7721
Sliding board	**1.0264**	1.2007	1.0788	0.6253
Standing aids	**0.8517**	0.9283	0.8372	0.7130

Study III reports the changes in unadjusted LBP intensity between baseline and follow-up, showing a significant increase in the moderate exposure group ($p<0.05$). Furthermore, the prevalence of back injuries at follow-up was 11%, 13% and 11% for the low, moderate and high exposure groups, respectively (Table 5).

Based on the fully-adjusted model described in paragraph 2.5.1, the risk of back injury at follow-up is shown in table 6. Using the moderate exposure group as reference, no significant differences in OR were found for the low- or high exposure groups (OR 1.14 and 1.36, respectively). Contrastingly, a significant difference in LBP intensity between the low- and moderate exposure groups was found (-0.50, p=0.0085), whereas no difference was found between the high- and moderate exposure groups (-0.19, p=0.2967) (Table 7).

Table 5 - Change in LBP (0-10) between baseline and follow-up and percentage of back injuries at follow-up. Values are presented as unadjusted means +/− standard error. Adapted from study III.

	LBP		**Injury**
Exposure Index	**Baseline Mean ± SE**	**Follow-up Mean ± SE**	**Follow-up %**
1st quartile	1.59 ± 0.12	1.60 ± 0.15	11
2nd & 3rd quartiles	1.78 ± 0.09	2.14 ± 0.12*	13
4rd quartile	1.42 ± 0.11	1.67 ± 0.15	11

Table 6 - Risk of back injury at follow-up.
Values are based on the fully-adjusted model and presented as odds ratios +/− 95% confidence intervals. Adapted from study III.

	Back Injury	
Exposure Index	**OR (95% CI)**	**p-value**
2_{nd} & 3_{rd} quartiles (comparator)	1	
1_{st} quartile	1.14 (0.52 - 2.51)	0.7367
4_{rd} quartile	1.36 (0.63 - 2.92)	0.4309

Table 7 - LBP at follow-up.
Values are based on the fully-adjusted model and presented as differences between least square means (LSM) +/− 95% confidence intervals. Adapted from study III.

	LBP	
Exposure Index	**LSM (95% CI)**	**p-value**
2_{nd} & 3_{rd} quartiles (comparator)	1.81	
1_{st} quartile	-0.50 (-0.89 - (-0.13))	0.0085
4_{rd} quartile	-0.19 (-0.57 - 0.18)	0.2967

Discussion

The main finding of this thesis is that low physical exposure during patient transfer is associated with lower LBP intensity at 1-year follow-up, whereas no association was found between exposure and risk of back injury (study III).
Furthermore, the presented exposure profiles for commonly-used assistive devices illustrate that the more technologically advanced transfer systems, e.g. intelligent beds and ceiling-lifts, result in lower physical load compared to no assistive device. Contrastingly, assistive devices used more manually (e.g. sliding boards) resulted in higher physical load (study II). This rejects the null-hypotheses introduced in paragraph 1.2.

The following discussion will attempt to shed light on the seemingly insurmountable list of possible factors influencing the patient transfer scenario, emphasizing that neither this thesis nor any other single project or intervention is likely to solve the emotionally-debated puzzle that constitutes the precarious working environment; seemingly inherent to the healthcare profession.

"Insufficient facts always invite danger" - Spock

4.1 Risk of back injury

The results presented in this project in relation to the outcome of back injury, i.e. physical exposure not being associated with risk of back injury, are in contrast to a number of previous studies reporting decreased injury rates with the implementation of various "no-lifting" policies (Alamgir et al., 2008; Andersen et al., 2014; Hunter et al., 2010; Schoenfisch et al., 2013; Zadvinskis and Salsbury, 2010). Indeed, recent meta-analyses indicate that interventions utilizing safe patient transfer programs (e.g. no-lifting policies and implementation of assistive devices) are efficacious in preventing and reducing the risk of musculoskeletal injuries (Hegewald et al., 2018; Teeple et al., 2017). However, given the low quality of evidence (Teeple et al., 2017) and failure to distinguish between individual program components of the included interventions (Hegewald et al., 2018), justified skepticism still exists regarding the efficiency of no-lifting policies as a single-mode intervention (Richardson et al., 2018; Verbeek et al., 2011). Following this, a recent systematic review evaluated interventions designed to prevent and reduce the impact of musculoskeletal injuries among nurses, reached the conclusion that none of the included types of interventions (e.g. lift systems and patient handling training) show consistent benefit in achieving this goal (Richardson et al., 2018). That being said, it is clear that numerous personal-, situational, environmental and population-specific factors influence the success of an intervention (Mitchell et al., 2009; Neupane et al., 2016; Sterud and Tynes, 2013). For example, age is found to be an important (confounding) factor in terms of occupational safety, with younger workers generally exhibiting an increased risk of injury (Laberge and Ledoux, 2011; Salminen, 2004).

A recent systematic review found that heavy lifting - as well as several psychosocial factors - were associated with greater risk of injury among younger workers in the Nordic countries when compared to their older colleagues (Hanvold et al., 2019). In healthcare workers, the potential effects of seniority may be guided by differences in how one approach the patient transfer scenario, as more experienced personnel have shown to exhibit different patterns of muscle activity (i.e. lower erector spinae and higher trapezius muscle activity) compared to their novice counterparts (Keir and MacDonell, 2004). Likewise, in a laboratory setting, the variations in techniques used during patient transfer have been found to influence the biomechanical load of the low-back more than the patient´s body mass and self-reliance (Skotte and Fallentin, 2008). This notion is further highlighted in the results presented in study II, where the relatively wide confidence intervals reported for each assistive device confirm the intuitive supposition that people, not excluding healthcare workers, inherently move and lift differently and with great context-specific and interpersonal variation. While the analyses performed in this project (study III) are controlling for numerous potential confounders, including age and seniority, it is likely that individual differences generally affect the degree of physical load imposed during patient transfer.

Further, while emphasizing the notion that "back injury" composes a relatively insensitive outcome both in terms of definition and accuracy of reporting, it seems evident that multiple factors influence injury rate. Therefore, the results from this project add to an already confused body of research by further indicating that physical exposure, by itself, is likely not the end-all-be-all of back injuries among healthcare workers.

"The fact that injury rates were not statistically significantly reduced may reflect the less sensitive nature of this indicator compared with the subjective indicators."

(Yassi et al., 2001)

4.2 Low-back pain

In contrast to the findings related to back injury discussed above, the results from this thesis illustrate that physical workload may represent one of several factors influencing the development of LBP among healthcare workers. Howbeit, while we report a possible preventative effect of low physical exposure, high physical exposure was not associated with pain intensity at follow-up. In terms of the latter, the discordance between this finding and the literature is apparent (Andersen et al., 2013; Milhem et al., 2016; Møller et al., 2019; Neupane et al., 2016; Oakman et al., 2017; Tipayamongkholgul et al., 2016). For example, using a prospective design including 5,136 workers, Oakman et al. found that high physical demands at work was associated with increased risk of multi-site pain among the general working population (OR 1.63) (Oakman et al., 2017), while a similar survey on 1,348 healthcare workers reports that accumulated physical exposure is highly related to multi-site pain (Neupane et al., 2016); hereby adding fuel to the proverbial fire. However, to put these findings into perspective which serves to 1) highlight the aforementioned controversy existing in the literature and 2) emphasize the surprisingly-overlooked & grossly-underestimated multifaceted biopsychosocial model of health and pain (Engel, 1977), several other work-related factors of interest deserve to be mentioned: For example, a recent prospective study using objectively measured exposure, reported that prolonged standing at work is associated with increased risk of LBP (Lunde et al., 2017), while data from the same cohort show that duration of >30 degrees (but not >60 degrees) forward bending is similarly associated with LBP (Lunde et al., 2019). Likewise, yet another questionnaire study investigating the effect of frequency of patient transfer on the risk of LBP found a positive association for healthcare workers who experienced LBP at baseline, but not for the ones who were pain-free (Holtermann et al., 2013). Moreover, another interesting finding is that a shorter workday decreased the prevalence of neck-shoulder (but not low-back) pain among healthcare workers with physically demanding care work (Wergeland et al., 2003), indicating that the accumulated time - and thereby often workload - may negatively influence some body regions and/or populations, but not others.

Finally, to finish the point, several other work-related factors - aside from the ones mentioned above - have been shown to influence the risk of LBP and MSDs, including but doubtfully limited to; static postures, sitting at work, work pace, night shift, short rest between shifts, patient size, bed height, high job- and emotional demands, frequent low mood, low job control, stress, social relations at work, job strain- and dissatisfaction (Boocock et al., 2019; Carneiro et al., 2017; Choi and Brings, 2015; Lee and Lee, 2017; Macfarlane et al., 2009; Mitchell et al., 2009; Ribeiro et al., 2017; Sterud and Tynes, 2013; Vedaa et al., 2019). In short, while the current body of evidence demonstrates a plethora of possible risk factors, the present thesis supports the notion that low physical exposure may play a preventative role in the development of LBP.

Entr'acte

From the list of studies referenced above and the varying degrees of both success and contention between interventions, it should be obvious that LBP is a complex beast not likely to succumb to half-assed insults to its dormant presence. As a logical consequence of this complexity, it should come as no surprise that there is presently no convincing evidence of efficacy for any single-mode intervention preventing LBP in workers (Richardson et al., 2018; Van Hoof et al., 2018; Verbeek et al., 2011). One almost cannot help but be thrown several minutes back into the past; vaguely remembering a similar conclusion for the outcome of back injury. This multiplex reality needs to be reflected not only in our hearts and minds, but ultimately also in the reading and interpretation of scholarly articles; including one's own.

However, as noted in the introduction of this thesis, the biomechanical aspect in this situation - which is comprised of a very specific population, working environment and range of job tasks - seems mostly influenced by the accumulated physical workload. Therefore, while vigorously reminding ourselves that this is only one piece of what is probably a relatively large X-rated puzzle, the remaining part of this discussion will direct its focus towards the possible barriers for appropriate use and implementation of assistive devices.

"Donning your super-nurse cape and lifting without help can do more harm to your body than you may realize" - the nurse who could lift. (Jones, 2017)

4.3 The Bigger Picture

At this point, one might be under the impression that the battle against MSDs is bound to go awry. Given the aforementioned dire state of events (e.g. shortages and prevalence of MSD) and list of possible influencing factors (e.g. biomechanical and psychosocial), the task at hand does indeed seem insuperable. However, a prudent first step seems to be the acknowledgment of the fact that there is no such thing as a quick and/or easy solution: The (often unforeseeable) practical aspects of daily life take precedence and will render even the most meticulously designed intervention obsolete. The goal can only be continuous progress; likely through a combination of context-specific implementations accounting for as many biopsychosocial- and practical influencers as possible.

Diving back into the biomechanical aspect of the conundrum, it is worrying that even though patient transfers only represent a small part of all nursing tasks (Holman et al., 2010), it is arguably the most commonly-reported cause of musculoskeletal injuries sustained by healthcare workers (Kim et al., 2012; Lipscomb et al., 2012; Pompeii et al., 2009; Yassi and Lockhart, 2013). One reason for the plurality of less-than-impressive results to date could partially be due to poor implementation of various safe-lifting initiatives: A US questionnaire survey found that 46% of the included nurses were not aware of safe-lifting guidelines, whereas only 33% and 39% indicated that the hospital had adequate staffing and equipment, respectively, to safely perform the required patient transfers (Vendittelli et al., 2016). Considering that equipment availability is one of the most cited factors influencing safe patient transfer (Kucera et al., 2019) and that nurses themselves perceive the availability of appropriate equipment as the most effective component in decreasing the frequency of unsafe patient transfers (Nelson et al., 2006), it seems evident that local organizational and monetary aspects pose a significant barrier for the implementation of safe-lifting policies.

Alongside equipment availability and understaffing, time constraints, easiness of use, accessibility, urgency, seniority and age, gender, night shifts, knowledge and perceptions about appropriate use, job satisfaction, height, patient mobility and size, job, physical workload, height, pain, staff- and patient preferences, are also known to influence use of assistive devices (Kucera et al., 2019; Lee and Lee, 2017; Noble and Sweeney, 2017; Richardson et al., 2019; Schoenfisch et al., 2019). Likewise, the inherent job demands and culture within healthcare are known to influence nurses to often put the safety of the patient before themselves (Holman et al., 2010), and the use of assistive devices have - in some instances - been associated with increased risk of skin- and fall-related adverse patient events (Elnitsky et al., 2014). Therefore, it is clear that multiple interpersonal, contextual, organizational and environmental barriers exist, and it is highly likely that several of these will sway (and topple) any given attempt at implementing safe-lifting strategies.
Figure 5 illustrates the multitude of factors influencing appropriate use of assistive devices.

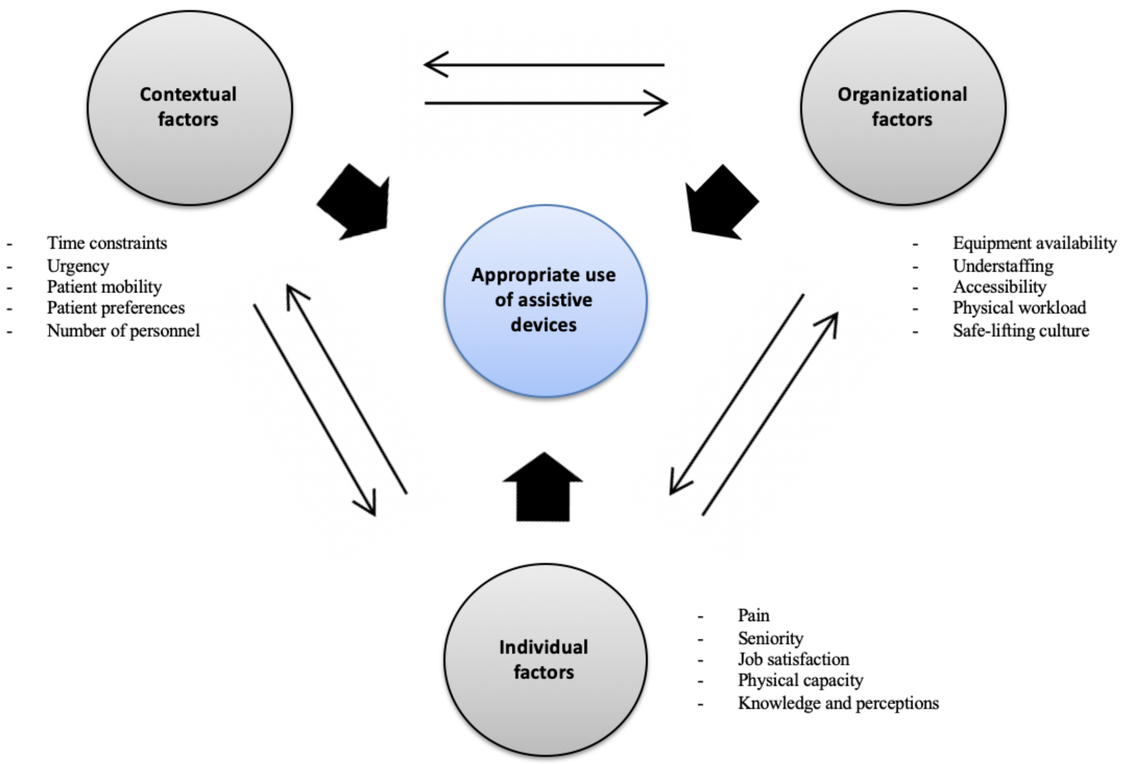

Figure 5 - Barriers to the use of appropriate assistive devices during patient transfer.

Considering the exhausting list of potential barriers listed above, it seems almost a logical consequence that most types of (perhaps insufficiently implemented) interventions fail to show any benefit. As mentioned, even though an overwhelming number of policies, legislations, safe transfer programs, guidelines, and interventions with the noble aim to prevent and reduce MSDs among healthcare workers is found in the literature (Edlich et al., 2005; Hudson, 2005; Richardson et al., 2018; Yassi et al., 2001), consistency is lacking: For example, even though it is commonly hypothesized that improving lifting technique (Hartvigsen et al., 2005; Kjellberg et al., 2003), utilizing friction-reducing devices (Bohannon, 1999; Skotte and Fallentin, 2008), focusing on manual handling training (Clemes et al., 2010; Retsas and Pinikahana, 2000) or improving ergonomics at the workplace (Hoe et al., 2018; Smedley et al., 2003, 1997) will result in positive outcomes related to MSDs, none of these interventions seem to confer any lasting benefit when reviewed systematically (Dawson et al., 2007; Freiberg et al., 2016; Hignett, 2003; Richardson et al., 2018; Thomas and Thomas, 2014; Verbeek et al., 2011). Once again considering the biopsychosocial view on health and pain - including the emerging implementation within clinical practice (Kusnanto et al., 2018) - it is perhaps not surprising that single-strategy interventions - such as the ones mentioned above - at best result in small and transient improvements.

Given the obvious lack of simplicity, it seems judicious that interventions and implementation policies alike should strive to encompass multiple aspects of the inextricable issue at hand. Within the field of pain research, LBP has long been acknowledged as a multifactorial phenomenon with branches intricately woven into all the knotty corners of the biopsychosocial model; characterized by potent influencers such as fear-avoidance, catastrophizing, sensitization, expectation, meaning, context etc. (Bingel and Tracey, 2008; Brodal, 2017; Ji et al., 2018; Kamper et al., 2015; Louw et al., 2016; Moseley, 2007; Moseley and Butler, 2015; Stochkendahl et al., 2018).

The overall conclusion is clear; pain is not simple. One is almost baffled by the fact that while this over-arching area of research has been promoting this notion for more than a decade, most interventions aimed at this issue fail to consider this inherent complexity. While reviewing the progressively-increasing amount of literature pertaining to somatic, psychological and social influencers is eons beyond the scope of this thesis, the recent LBP-series in the Lancet does an excellent job of detailing current shortfalls and opportunities for prevention, treatment as well as promising (multidimensional) directions, - making it almost a mandatory read for everyone within this field of research (Buchbinder et al., 2018; Foster et al., 2018; Hartvigsen et al., 2018).

"Pain is modulated by many factors from across somatic, psychological and social domains."

(Moseley, 2007)

Within the local realm of healthcare, however, a significant portion of this discussion is dedicated to highlighting the notorious need for multifaceted interventions as well as improved implementation strategies. At this point in time, research policies on musculoskeletal conditions tend to direct its focus towards treatment modalities while lacking emphasis on the importance of implementation (Bourne et al., 2018), which - perhaps partially as a result - is reflected in the fact that very few preventative interventions related to patient transfer include quantification of effectiveness and compliance (Koppelaar et al., 2009). However, examples of successful, multifaceted, long-term implementation strategies do exist (Dennerlein et al., 2017; Olinski and Norton, 2017). For example, the study by Olinski & Norton describes how an 82% reduction in patient transfer injuries has been sustained for an 8-year period since the program´s step-by-step implementation; with key factors including involvement of stakeholders, removing barriers against change, empowering personnel to act, quantifying outcomes and continually striving for progress (Olinski and Norton, 2017).

"None of the studies quantified their impact on effectiveness nor on compliance and adherence to the intervention." (Koppelaar et al., 2009)

Following this, even though the abovementioned study is one of a kind in terms of the commendable level of implementation and follow-up, an increasing number of studies have surfaced showing that even less ruminative multimodal interventions may prove beneficial in the battle against MSDs; hereby possible succeeding where most single-mode implementation strategies have failed (Aslam et al., 2015; Dennerlein et al., 2017; Lim et al., 2011; Zadvinskis and Salsbury, 2010). For example, a program evaluation with 1-year follow-up among 1,832 healthcare workers showed that a systems approach, including the integration of "best practice" models into the patient´s plan for care, was associated with improved work practices as well as a reduction in injuries (Dennerlein et al., 2017). Likewise, a pilot study using a mixed measures design explored the effects of a multifaceted minimal-lift environment (including environmental, administrative and behavioral aspects) on equipment use and injury, and reported positive outcomes in terms of greater use of assistive devices and lower injury rates compared to control (Zadvinskis and Salsbury, 2010). Lastly, a Canadian study including 1,480 healthcare workers from 6 different hospitals aimed to evaluate the implementation of a multifactorial ergonomics program (including staff education, needs assessment and skill development), and found that the intervention group experienced 38% lower odds of repeated injury due to patient transfer (Lim et al., 2011).

These findings are echoed in the conclusions of several reviews; consistently advocating and showing benefit of a multidimensional approach to reducing MSDs among healthcare workers (Bos et al., 2006; Goldgruber and Ahrens, 2010; Hignett, 2003; Thomas and Thomas, 2014; Tullar et al., 2010).

"The greatest results are achievable through comprehensive multimodal (or systemic) programs including relational and behavioral elements." (Goldgruber and Ahrens, 2010)

Summarily, the multifactorial imp of the working environment is in dire straits: It is unceremoniously characterized by various single-mode research modalities trying to identify the one to rule them all, feeble interventions lacking proper implementation strategies, a grievously complex interaction between organizational, contextual, social and environmental influencers and a prolongation that has resulted in its now deeply-rooted, fundamental part of the culture. By utilizing both objective measurements and a prospective questionnaire, the present project provides further evidence of accumulated physical load as a possible risk factor for LBP, while highlighting the need for more comprehensive interventions and implementation strategies that this field of research so desperately yearn for.

4.4 Strengths and limitations

Limitations of this project primarily include the inherent shortcomings related to the methodology; the majority of which have also been mentioned in the methods section as well as in study II and III: The technical measurements used in study II are subject to their intrinsic variability (e.g. stochastic signal and susceptibility to interference), which made the need for strict standardization necessary. However, given the single-day repeated-measures design and accompanying normalization procedures, the aforementioned variability is very unlikely to systematically influence the results in any one direction. Likewise, the limitations of using accelerometry for quantification of dynamic trunk inclination have been discussed in the methods section as well as in study II, and the method was deemed appropriate based on the cited literature.

Additionally, a potential limitation of using “no assistive device” as a reference exists, as it may be that the associated muscle activity is underestimated due to the type of (very self-reliant) patient typically being transferred without the use of assistive devices. Following this, while these analyses do not account for the type of patient transfer being performed, it is likely that the use of selective assistive devices is preferred during specific transfer scenarios.

However, while maintaining the level of detail, a more pragmatic estimate of the true exposure associated with each individual assistive device can only be achieved by systematic identifying the types of patient transfers most strongly associated with the assistive device in question, as the individual exposure profiles presented herein should be seen in relation to the specific lifting scenarios during which they are most commonly used.

Further, the previously-inferred notion that people move and lift differently and with great variability will - in addition to the fact that this project included a specific population of females - invariably influence the generalizability of these results outside this population. Likewise, this interpersonal variability questions the viability of applying technical measurements of exposure to a larger cohort.

Lastly, the limitations pertained to the prospective questionnaire design include recall- and non-response bias, as well as the likely under-reporting of MSDs seen in this population (Menzel, 2008). Therefore, as the true prevalence of back injuries and LBP is likely to be even higher than what is possible to accurately deduce from questionnaire surveys, this will influence the validity of any established (or missing) associations with physical exposure.

Strengths include the fact that technical measurements of physical load were performed throughout 52 full workdays in Danish hospitals; hereby reflecting real-life transfer scenarios. Likewise, the combination of 1) developing an exposure matrix based on objective measurements from a representable population covering a wide range of commonly used assistive devices and 2), applying these on a prospective cohort of healthcare workers in order to gauge any preventative/aggravating effects of physical exposure, constitutes another unambiguous strength of this project. The importance of combining these research methodologies should not be neglected; - not solely because of the clear strength of acquiring real-life measurements, but primarily due to the poor validity of accurately identifying and quantifying work-related physical exposure based on questionnaire surveys alone (Koch et al., 2016). Therefore, a multidisciplinary modus operandi is most likely a viable approach to more precisely identifying appropriate preventive strategies, and future research projects determined to quantify physical exposure at the workplace should strive to further increase the level of detail in the technical measurements; i.e. including additional aspects of the specific transfer scenario, and hereby improve the specificity of the exposure matrix.

Conclusions

This thesis provides measurements of physical load and trunk inclination during patient transfer among Danish healthcare workers, presented as an exposure matrix including commonly used assistive devices. Notwithstanding the aforementioned caution when applying the results from study II to all types of patient transfer scenarios, it is likely that frequent use of ceiling-lifts and intelligent beds will contribute to decreasing the physical workload. Likewise, study II report indicators of fatigue at the end of the workday, which corresponds to the notion that it may prove beneficial to consistently utilize assistive devices associated with lower physical load. In study III, low physical exposure was prospectively associated with lower intensity of LBP at 1-year follow-up, whereas no effect of physical exposure was seen for the outcome of back injury. In conclusion, while a small army of influencers arguably contributes to the prevalence of MSDs, consistent use of appropriate assistive devices may play a role in preventing LBP. However, given the complexity of the situation at hand, research strategies would likely benefit from viewing the present conundrum through a wider lens: Future policies, interventions, and implementations at local hospitals should therefore not only consider how to decrease physical exposure during work but also how to sustainably implement multifaceted programs while accounting for several of the possible barriers innate to the working environment of healthcare workers.

"Quis Custodiet Ipsos Custodes?" - Juvenal

Outro

Congratulations! I hope you were woke enough to also identify the LOTR, Shakespeare, and Dream Theater references, as they will undoubtledly have contributed to a heightened reading experience. Alas, this also means that the journey is over, and I will be accepting both praise and ridicule in the appropriate order and magnitude. Until then: Live long and prosper.

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